REMARKS

The remainder of this amendment is set forth under appropriate subheadings for the convenience of the Examiner.

Claim Amendments

Independent Claims 1, 21, 23 and 28 have been amended to include the limitations that the superheated alloy is cooled to a temperature between a solidus temperature and a liquidus temperature of the alloy to thereby form a nucleated alloy. These claims have also been amended to include the limitation that the nucleated alloy is subsequently mixed at the temperature between a solidus temperature and a liquidus temperature of the alloy, without raising the temperature of the alloy to thereby prevent the nuclei from melting, for a period of time of at least about ten minutes. Further, these claims have been amended to include the limitation that the nucleated alloy is subsequently cooled to a temperature below the solidus temperature at a rate of less than about 0.7° C per second when above the solidus temperature, thereby forming an alloy having an average particle size of about 100μm or less and substantially free of dendrites. Support for these amendments to the claims can be found in the specification at, for example, page 11, lines 21 through 22; page 17, lines 18 through 22; page 19, lines 6 through 18; page 20, line 20 through page 21, line 17; page 22, lines 9 through 15; page 25, line 12; and page 26, line 20. No new matter has been added.

New Claims 29 and 30

New dependent Claims 29 and 30 have been added to specifically point out two embodiments of the generic method of Claim 1. In particular, new Claim 29 includes the additional steps of cooling the superheated alloy of step a. of Claim 1 to a temperature below the solidus temperature and then raising the temperature of the alloy to the temperature of step b. between the solidus temperature and the liquidus temperature. Support for new Claim 29 can be found at, for example, page 9, lines 8 through 10 (thixocasting); page 11, lines 16 through 21; page 13, lines 19 through 20; and Examples 1 and 2 (pages 17, line 1 through page 22, line 23). No new matter has been added.

New Claim 30 includes the additional limitation that the nucleated alloy of step b. of Claim 1 is formed by cooling the superheated alloy of step a. directly from a temperature above the liquidus temperature to a temperature of step b. between the solidus temperature and the liquidus temperature. Support for new Claim 30 can be found in the specification at, for example, page 9, lines 8 through 10 (rheocasting); page 11, lines 12 through 16; page 13, lines 17 through 18; and in Examples 3 through 5 (page 22, lines 25 through page 31, line 25). No new matter has been added.

Examiner's Comments

The Examiner stated that there appears to be a typographical error on page 15 of the specification in that reference to "Reactor 30" should be "Reactor 26."

The specification has been amended in response to the Examiner's comment. No new matter has been added.

Rejection of Claims 1, 4, 14 and 28 Under 35 U.S.C. § 102(e) or, in the Alternative, Under 35 U.S.C. § 103(a) Over U.S. Patent Number 6,645,323 (Flemings et al.)

Claims 1, 4, 14 and 28 stand rejected under 35 U.S.C. § 102(e) as anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over U.S. 6,645,323, issued to Flemings et al. In particular, the Examiner stated that Flemings et al. disclose a process for preparing a metal alloy when the alloy is melted and then rapidly cooled while being vigorously agitated. The Examiner also stated that, since the solids formed by the method of Flemings et al. are substantially free of eutectic metal compositions, either it is inherent that essentially all of the nuclei formed are substantially free of "entrapped liquid" or, in the alternative, a person of ordinary skill in the art at the time the invention was made would expect that, if the solids were substantially free of eutectic metal composition, the nuclei would be substantially free of entrapped liquids.

Flemings et al. teach a method of forming a skinless metal alloy composition free of entrapped gas and comprising primary solid discrete degenerate dendrites homogenously dispersed within a secondary phase. As described in Example Ia, at Col. 6, line 56 through Col. 7, line 9, an alloy at a temperature above its liquidus temperature is agitated by immersing a

rotating rod and rapidly cooled to below its liquidus temperature over a period of time of about 15 seconds, at which time the rotating rod was removed and the melt cooled to below its solidus temperature:

> About 405 grams of A356 aluminum alloy stock were melted in a high-density graphite crucible 3 inches tall, with a 2.5 inch inner diameter, and a 0.25 inch wall thickness. The crucible was placed inside an air-circulating resistance furnace, which was programmed to slowly cool the melt to a temperature 7° C above its liquidus temperature. After holding at that temperature for several minutes, a solid copper rod with a 0.5 inch diameter, rotating at 1236 rpms, and initially at room temperature, was introduced in the furnace through an opening in its top and immersed into the melt 1.8 inches. The immersed, rotating rod provided a combination of rapid cooling and vigorous agitation of the melt. This led to a rapid decrease of the melt temperature, which dropped below the liquidus temperature, causing copious nucleation of primary aluminum particles. The rotating rod remained in the melt for 15 seconds, dropping the melt temperature to 615° C., about 2° C. below the liquidus temperature, which corresponds to about 3% fraction solid. After the combined cooling and agitation period, the rod was removed from the melt, and the melt was cooled and solidified completely.

Similarly, in Example Ib, a melt was cooled from 3° C above its liquidus temperature to a temperature about 1° below its liquidus temperature over a period of about 30 seconds and then subsequently solidified completely (Col. 8, lines 5 through 7). In Example 2, a melt was cooled from 6° C above the liquidus temperature to a temperature 9° C below the liquidus temperature with agitation over a period of 32 seconds and then solidified completely (Col. 8, lines 42 through 47).

There is no disclosure or suggestion in Flemings et al. of a method that includes reducing the temperature of an alloy from above its liquidus temperature to a temperature between its solidus and liquidus temperatures and maintaining the temperature for a period of time of at least 10 minutes without raising the temperature to thereby prevent nuclei from melting, followed by cooling the resulting nucleated alloy to below the solidus temperature, as claimed by Applicants in independent Claims 1 and 28. Dependent Claims 4 and 14 depend from independent Claim 1.

Therefore, the subject matter of Claims 1, 4, 14 and 28 is not anticipated by the teaching of Flemings et al. under 35 U.S.C. § 102(e).

Applicants have discovered that known methods, such as disclosed by Flemings et al. whereby mechanical stirring is employed to break up dendrites and thereby produce thixotropic metal structures, can be avoided by cooling an alloy from a temperature above its liquidus temperature to a temperature between the solidus and liquidus temperatures and maintaining that temperature, without raising it to thereby prevent nuclei from melting for a period of at least about 10 minutes. Significant disadvantages associated with known methods of mechanical stirring and rapid cooling are thereby avoided, as stated by Applicants in the specification at page 3, lines 29 through page 4, line 5:

> During the initial years of SSM process development, mechanical stirring was used in various ways to break up dendrites and produce thixotropic metal structures. The combination of rapid heat extraction and vigorous melt agitation was effected by using different sizes, shapes, and velocities of stirring rods. Various researchers addressed the evolution of the "stircast" structure during this time. Although these methods worked well in that they effectively produced the desired metal structures, erosion of the stirrer became the "weak link" of the process.

Applicants, on the other hand, have overcome these disadvantages, as stated in the specification at page 6, lines 23 through 30, for example,

> The present invention has many advantages. This invention provides for semi-solid metal production process simplicity, control over semi-solid metal structure evolution, and the fast adjustment of physical characteristics of the slurry produced (e.g., solid fraction and the size of nuclei). This invention allows for the production of semi-solid slurries without the need to break up dendrites through external stirring of the metal slurry. Hence, this invention eliminates the need to use, repair, replace, and maintain mechanical stirring rods or expensive and complicated electromagnetic stirring mechanisms.

Applicants also have demonstrated the significance of maintaining the temperature of an alloy between the solidus and liquidus temperatures for a period of at least about 10 minutes in

the experimental portion of their application. For example, as stated at page 17, lines 14 through 22; at page 20, line 20 through page 21, line 7; and at page 22, lines 9 through 15:

> Figures 3A, 3B, 4A, 4B, 5A, and 5B exhibit the representative micrographs from the T1-2, T1-3, and T1-4 experiments, respectively. The as-solidified micrographs are shown in Figures 3A, 4A, and 5A, while the micrographs on Figures 3B, 4B, and 5B show the microstructure obtained after reheating to 585° C and holding for 10 minutes, followed by immediate quenching in water. The microstructures in Figure 3B had a residence time of reheated slug in semi-solid metal range of about 38 minutes. The microstructures in Figure 4B had a residence time of reheated slug in the semi-solid metal range of about 25 minutes. The microstructures in Figure 5B had a residence time of reheated slug in semi-solid metal range of about 18 minutes.
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> Figure 6A shows the micrograph for the as-solidified structure of experiment T2-4, and Figure 6B shows the reheated micrograph that had a 24-minute residence time in the SSM temperature range. Figure 7A shows the micrograph for the as-solidified structure of experiment T2-5, and Figure 7B shows the reheated micrograph that had a 25-minute residence time in the SSM temperature range. Figure 8A shows the micrograph for the as-solidified structure of experiment T2-6, and Figure 8B shows the reheated micrograph that had a 16-minute residence time in the SSM temperature range. Figure 9A shows the micrograph for the as-solidified structure of experiment T2-8, and Figure 9B shows the reheated micrograph that had a 2-minute residence time in the SSM temperature range.
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> Figure 9B reinforces the reasoning presented above concerning the requirement of a small solid fraction of the slurry upon exit. The exit temperature was 618° C, and these microstructures show the highest degree of dendritic growth. This is because the majority of nuclei formed within the receiving crucible rather than the reactor; therefore there was a lower [sic] cooling rate through the alloy's liquidus temperature. Upon reheating and quenching, the dendrites in the as-solidified structure coarsened, but did not approach the level of sphericity observed in the previous reheated samples.

As described in the specification, and seen from the micrographs described therein, experiment T2-8, represented by Figures 9A and 9B, had the shortest period of residence time in a temperature range between the solidus temperature and the liquidus temperature and, also, represented the only sample that exhibited dendritic growth. Therefore, Applicants have demonstrated the advantage of the method, as claimed, relative to Flemings et al., which rapidly cools a super heated alloy to a temperature below the liquidus temperature and makes no mention of subsequent cooling of the alloy to below the solidus temperature. Relative to the teaching of Flemings et al., Applicants' claimed method meets the requirements for non-obviousness under 35 U.S.C. § 103(a).

Rejection of Claims 18-21 Under 35 U.S.C. § 103(a) As Being Anticipated Over Flemings et al.

Claims 18-21 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al. In particular, the Examiner stated that, with respect to Claims 18-20, it would have been obvious to one of ordinary skill in the art the time the invention was made to direct the semi-solid alloy to forming with a solids volume fraction of between 40 and 50%, since Flemings et al. disclose that the preferred range is between 10 and 55%. With respect to Claim 21, the Examiner stated that making a process continuous is prima facie obvious in light of a batch process taught by prior art.

Claims 18-20 depend directly from or indirectly from independent Claim 1. Therefore, the subject matter of these claims meets the requirements of 35 U.S.C. § 103(a) in view of Flemings et al. for the same reasons described above that the subject matter of independent Claim 1, as amended, meets the requirements of 35 U.S.C. § 103(a) in view of Flemings et al.

Claim 21 is an independent claim, and has been amended in the same way that Claim 1 has been amended. Therefore, Claim 21 meets the requirements of 35 U.S.C. § 103(a) in view of Flemings et al. for the same reasons that the subject matter of independent Claim 1 meets the requirements of 35 U.S.C. § 103(a) in view of Flemings et al.

Rejection of Claims Under 35 U.S.C. § 103(a) Over Flemings et al. and Further in View of U.S. Patent No.: 5,701,942, Issued to Adachi et al.

Claims 2, 3, 5, 7, 8, 10-12, 15 and 16 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al., as applied to Claim 1, and further in view of U.S. Patent No.: 5,701,942, issued to Adachi et al. In particular, the Examiner stated that, with respect to Claims 2 and 3, Flemings et al. do not disclose that the alloy is cooled at a rate of at least 15° C per second as in instant Claim 2 or that the cooling rate is in the range of about 20-30° C per second as in instant Claim 3. The Examiner further stated that it would have been obvious to one of ordinary skill in the art at the time the invention was made to cool the alloy from superheat at a rate of at least 15° C per second or in a range of 20-30° C per second as taught by Adachi et al. in the process of Flemings, et al. to produce small size grains within practical limits of cooling rate as taught by Adachi et al.

With respect to Claims 5 and 16, the Examiner stated that Flemings et al. disclose that the alloy can be further processed by forming from the liquid melt or by solidification, and then reheated, but that Flemings et al. do not teach a process step for forming in a specific thixocasting or rheocasting application, as in instant Claim 5, or that a billet is formed as in instant Claim 16. Nevertheless, the Examiner stated that it would have been obvious to one of ordinary skill in the art at the time the invention was made to form a billet in the thixocasting process of Adachi et al. with the alloy of Flemings et al., since Flemings et al. teach that the alloy can be processed by a solidification of the alloy and Adachi et al. teach that this is a simple process for producing a billet to find equiaxed crystals.

Regarding Claims 7, 8 and 10-12, the Examiner stated that Flemings et al. do not teach the particle sizes of these claims, nor that the alloy is quenched, or the use of aluminum or titanium borides as grain refiners. However, the Examiner states that Adachi et al. disclose the teachings lacking in Flemings et al. and that it would have been obvious to one of ordinary skill in the art at the time the invention was made to use grain refiners and quenching as taught by Adachi et al. with the alloy of Flemings et al. to produce a fine grained casting with a crystal grain size of 50 microns as taught by Adachi et al.

With respect to Claim 15, the Examiner stated that Flemings et al. do not teach that the alloy superheated to a temperature in the range of between about 10 and 15° above the liquidus

temperature, but that Adachi et al. teach heating the superheated alloy to a temperature that overlaps Applicants' claimed range, and that, since Adachi et al. teach that any superheat not more than 30° C is suitable for producing fine equiaxed crystals, it would have been obvious to one of skill in the art at the time the invention was made to superheat the melt as claimed by Applicants.

As discussed above, Applicants have amended the independent claims to include the limitations that the superheated alloy is cooled to a temperature between a solidus temperature and a liquidus temperature to form a nucleated alloy, and mixing the nucleated alloy at that temperature for a period of time of at least 10 minutes, while preventing nuclei from melting by not raising the temperature of the alloy, prior to cooling the alloy to a temperature below the solidus temperature. Applicants have further amended the independent claims to include the limitations that the rate of cooling of nucleated alloy to a temperature below the solidus temperature is conducted at rate of less than about 0.7° C per second, and that the resulting alloy substantially free of dendrites has an average particle size of about 100 micrometers or less. Support for these amendments to the claims can be found in the specification, for example, at page 11, lines 22 and 23, at page 25, lines 11 through 12 and at page 26, lines 18 through 21. No new matter has been added.

There is no disclosure or suggestion in Flemings et al. of cooling a nucleated alloy to below the solidus temperature at a rate of less than about 0.7° C per second to form an alloy substantially free of dendrites and an average particle size of about 100 micrometers or less. Flemings et al. are silent with respect to the rate of cooling of the nucleated alloy from a temperature between the solidus and liquidus lines to a temperature below the solidus line.

Adachi et al. do not remedy the deficiencies of Flemings et al. Specifically, as noted by the Examiner, to the extent that Adachi et al. discuss cooling of any alloy, Adachi et al. teach that cooling at a rate of less than 1° C per second does not produce fine equiaxed crystals. For example, as stated by Adachi et al. at Col. 6, lines 23 through 30:

> Discussion is first made with reference to FIG. 1. If the casting temperature is higher than the melting point by more than 30° C or if the rate of cooling in the solidification zone is less than 1° C./sec. satisfactorily fine, equiaxed crystals are not obtainable even if grain refining agents are contained. To avoid this problem, the

> casting temperature is set to be higher than the liquidus line by 30° C. or less and the rate of cooling in the solidification zone is set to be at least 1.0° C./sec.

Further, as can be seen in figures in Adachi et al., the rate of cooling described therein continues from a starting point at least within a temperature between the solidus line and the liquidus line. Therefore, the rate of cooling taught by Adachi et al. of at least 1° C per second also applies to cooling rates within the temperature range between the solidus line and the liquidus line and, accordingly, Adachi et al. teach away from cooling within the two phase region, between the solidus line and the liquidus line, at a rate of less than about 0.7° C per second, as claimed by Applicants.

Therefore, there is no disclosure or suggestion in view of Flemings et al., or Adachi et al., taken either separately or in combination, of Applicants' claimed method, as set forth in the independent claims, as amended. Claims 2, 3, 5, 7, 8, 10-12, 15 and 16 depend directly or indirectly from independent Claim 1 and, therefore, these claims also meet the requirements for non-obviousness under 35 U.S.C. § 103(a) in view of Flemings et al. and Adachi et al., taken either separately or in combination.

<u>Rejection of Claims Under 35 U.S.C. §103(a) Over Flemings et al. and Further in View of U.S. 5,464,053, Issued to Moschini</u>

Claims 5, 6 and 22 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al. as applied to Claim 1 and further in view of U.S. 5,464,053, issued to Moschini. In particular, the Examiner stated that Moschini discloses a process for forming rheocast ingots by smelting metal alloy and feeding the alloy under laminar flow conditions through a static mixer so as to obtain a semiliquid rheocast material at the outlet of the mixer, and that it would have been obvious to one of ordinary skill in the art at the time the invention was made to use the static mixing rheocast method of Moschini with the alloy of Flemings et al., since Flemings et al. disclose that the alloy can be further processed by forming the liquid melt and the static mixing method of Moschini prevents gas inclusions in a molten alloy.

Moschini does not remedy the deficiencies of Flemings et al. as applied to independent Claim 1 from which Claims 5 and 6 depend. Claim 22 has been canceled. There is no disclosure

or suggestion in Flemings et al. or Moschini, taken either separately or in combination, of Applicants' claimed method as set forth in amended Claim 1. Therefore, remaining dependent Claims 5 and 6 meet the requirements of 35 U.S.C. § 103(a) in view of these references, taken either separately or in combination.

Rejection of Claim 9 Under 35 U.S.C. § 103(a) in View of Flemings et al. and Martinez et al.

Claim 9 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al. in view of Martinez et al. ("Efficient Formation of Structures Suitable for Semi-Solid Forming," Transactions 21st Century International Die Casting Congress & Exposition, October 29 - November 1, 2001). The Examiner stated, in particular, that Martinez et al. teach shape factors between 0.75 and 0.95 and that it would have been obvious to one of ordinary skill in the art at the time the invention was made to adjust the stirring speed as taught by Martinez et al. in the process of Flemings et al. to achieve a shape factor in the range of 0.75 to 0.95 as disclosed by Martinez et al.

Martinez et al. does not remedy the deficiencies of Flemings et al. as applied to amended independent Claim 1. Therefore, neither Flemings et al. nor Martinez et al., taken either separately or in combination, make the subject matter of Applicants' method as set forth in amended Claim 1 obvious under 35 U.S.C. § 103(a). Claim 9, which depends from independent Claim 1, also meets the requirements of 35 U.S.C. § 103(a).

Rejection of Claims 23-27 Under 35 U.S.C. § 103(a) in View of EP 0 745 694 (EP '694) and Flemings et al.

Claims 23-27 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over EP '694 in view of Flemings et al. The Examiner stated that EP '694 discloses a method and apparatus for semisolid forming of alloys with fine-grain spherical structure in a convenient, easy and inexpensive manner but does not disclose that the nuclei are essentially free of entrapped liquid, as set forth in instant Claim 23. However, the Examiner also stated that it would have been obvious to one of ordinary skill in the art at the time the invention was made to incorporate the mixing and cooling steps of Flemings et al. into the mixed alloy casting process of EP '694 to produce an alloy with nuclei substantially free of entrapped liquid as taught by Flemings et al.

With respect to Claim 24, the Examiner stated that EP '694 teach alloys that are dissimilar. With respect to Claim 25 the Examiner stated that EP '694 teach alloys that have different melting points but are heated to the same degree of superheat. With respect to Claims 26 and 27, the Examiner stated that, assuming the "first metal" is the higher melting point metal, the superheat given in Table 9 of EP '694, as ranging from 0-15°C superheat, would be within the range of between 1° C and 50° C superheat above the liquidus temperature of the lower melting point second metal as in instant Claim 26, and that the superheat of the second metal is given as between 1 and 20° C superheat, which is within the Applicants' claimed range of between 1 and 50° C superheat, as in instant Claim 27.

Independent Claim 23 has been amended to include the same limitations as that of independent method Claim 1. Claims 24 through 27 depend from independent Claim 23.

EP '694 does not remedy the deficiencies of Flemings et al., as applied to independent Claim 23. Therefore, neither Flemings et al. nor EP '694 disclose or suggest Applicants' method as set forth in amended independent Claim 23, nor dependent Claims 24-27. As amended, independent Claim 23 and dependent Claims 24-27 meet the requirements of 35 U.S.C. § 103(a) in view of Flemings et al. and EP '694, taken either separately or in combination.

Rejection of Claim 13 Under 35 U.S.C. § 103(a) over Flemings et al. Over Adachi et al. and Further in View of ASM Metals Handbook

Claim 13 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al. in view of Adachi et al. as applied to Claim 11 and further in view of the ASM Metals Handbook, Ninth Edition, Vol. 15, Casting. The Examiner stated that it would have been obvious to one of ordinary skill in the art at the time the invention was made that the Ti and B added to the alloy of Flemings et al. in view of Adachi et al. for grain refinement would form borides including TiB_2 as taught by the ASM Metals Handbook.

The ASM Metals Handbook does not remedy the deficiencies of Adachi et al. or Flemings et al. as applied to independent Claim 1 from which Claim 13 indirectly depends. Therefore, the subject matter of Claim 13, as with that of independent Claim 1 as amended, meets the requirements of 35 U.S.C. § 103(a) in view of these references, taken either separately or in any combination.

Rejection of Claim 17 Under 35 U.S.C. § 103(a) in View of Flemings et al., Moschini and U.S. 6,908,590 (DasGupta)

Claim 17 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over Flemings et al. as applied to Claim 1 and further in view of Moschini and U.S. Patent No.: 6,908,590, issued to DasGupta. The Examiner stated that Flemings et al. in view of Moschini disclose a process for rheocasting ingots by smelting a metal alloy and feeding that alloy under laminar flow conditions through a static mixer to obtain a rheocast material. The Examiner further stated that it would have been obvious to one of ordinary skill in the art at the time the invention was made to recycle scrap as taught by DasGupta from the forming process of Flemings et al. in view of Moschini to the smelting process of Flemings et al. in view of Moschini to benefit from the cost savings as taught by DasGupta.

DasGupta does not remedy the deficiencies of Flemings et al. or Moschini, taken either separately or in combination. Therefore, Claim 17, which depends from independent Claim 1, is not obvious in view of Flemings et al., Moschini or DasGupta, taken in any combination, under 35 U.S.C. § 103(a).

Summary and Conclusions

The specification has been amended as requested by the Examiner to correct a minor, self-evident, typographical error and it also involves no new matter. Independent Claims 1, 21, 23 and 28 have been amended in view of the references cited by the Examiner. Dependent Claims 14 and 15 have been amended to be consistent with independent Claim 1, as amended. New Claims 29 and 30 have been added as distinct embodiments under the generic scope of independent Claim 1 to cover both thixocasting and rheocasting applications, respectively. No new matter has been added in any of the amendments to the claims. As amended, Applicant' claimed method and alloy formed by the method meet the requirements of 35 U.S.C. § 102 and 103, taken separately or in any combination. As amended, it is believed that the application is now in condition for allowance.

If the Examiner believes that a telephone conference would expedite prosecution, he is invited to call Applicants' undersigned attorney.

Respectfully submitted,

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